Extraction of Biodiesel from Sunflower Oil and Evaluating its Performance and Emission Characteristics in DI Diesel Engine

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ABSTRACT

Due to the depleting fossil fuel resources biodiesel is gaining more and more importance as an attractive fuel. However the high cost of biodiesel is the main hurdle to commercialization of the product. Biodiesel is monoalkyl esters of long chain fatty acids which are derived from renewable feed stock like vegetable oils and animal fats. It is produced by transesterification in which oil or fat is reacted with a monohydric alcohol in presence of an alkaline catalyst. In this work, biodiesel is extracted from sunflower oil and its performance and emission characteristics are studied in diesel engine. Experiments were performed using neat diesel, neat biodiesel and its blend i.e B20. Fuel properties like calorific value, flash point and cetane value of biodiesel and biodiesel–diesel blends were found comparable to diesel. Performance results reveal that for biodiesel and blend have brake thermal efficiency, brake-specific fuel consumption are comparable with diesel. Emission results showed that in most cases HC and CO are considerably reduced for diesel and its blend except NOx. From the results obtained it is clear that the biodiesel extracted can be used as fuel in direct injection diesel engine without much modifications**.**

Keywords—*Biodiesel, Performance, emission, sunflower oil, transesterification.*

I. INTRODUCTION

Increased interest in renewable fuels is attributed to increase in the cost of conventional fuels, environmental concerns associated with fossil fuels, and government support in terms for subsidies for the development and production of renewable fuels. Due to the continuous increase in the price of the petroleum products and the environmental concerns about pollution coming from the vehicles , biodiesel is becoming a developing area of high concern. There are different ways of production, with different kinds of raw materials: refined crude or frying oils. The use of biodiesel has many advantages like it's portability, ready availability, better combustion efficiency, lower sulphur content, higher cetane number, higher biodegradability, domestic origin, higher flash point and improved lubrication property.

High viscosity and low volatility are the main drawbacks of vegetable oil. These factors affect the combustion in diesel engines. A process called transesterification reduces the viscosity to a value comparable to that of diesel and hence improves combustion. When compared to diesel biodiesel emits fewer pollutants over the whole range of air–fuel ratio..

In this present work, biodiesel is extracted from sunflower oil and to investigate the performance and emission characteristics of a diesel engine fuelled with sunflower oil and its blends compared to that of standard diesel.

II. OBJECTIVE

The main objective is to carry out the performance and emission analysis of vegetable oils in the form of Bio-Diesel (Sunflower Oil) in a single cylinder Compression ignition Engine. To test with different blends with Bio-diesel so as to optimize the different emissions level based upon the different observations made.

III. BIODIESEL EXTRACTION PROCESS

The biodiesel extraction process has two starting points. If the free-fatty acid content is less than 2.5%, then the process starts from transesterification process. If the free-fatty acid content is more than 2.5%, then esterification has to be done before starting the transesterification process. In this work, biodiesel is extracted from sunflower oil with methanol and potassium hydroxide as catalyst.

A. Components and Materials Description

1) Tank

Tank is the component which contains all the reaction solutions i.e. oil, methanol and catalyst. Therefore, it should be tough, leak proof and with stand temperature. Thus, the tank is made of polymethyl methacrylate, commonly known as acrylic tubes. It is transparent, light in weight, good impact strength, and high heat resistance and weather resistant. An outlet pipe is provided at the bottom of the tank for draining out the biodiesel.

Parameters	Value
Dimensions	Diameter-20cm Height-28cm
Thickness	10mm
Capacity	7 litres

2) Heater

Heater is used in order to heat the reaction mixture to a desired temperature. Resistance of the coil material is the key point to heating process. Heater is connected next to the thermostat to obtain desired heating effect.

Parameters	Value
Heater Material	Stainless Steel
Power	1500W
Voltage	230V,50Hz
Current	7A

3) Thermostat

It senses the temperature of a system and maintains the system's temperature near a desired set point. It senses the reaction mixture temperature and cuts off the power to the heater when desired temperature is reached.

4) Electric Motor and Stirrer Rod

Electric motor is used to drive the mechanical stirrer which is used to stir the mixture at a constant speed in order to attain uniform composition of the reaction mixture.

5) Settling Flask

It is used to cool down the reaction mixture after heating and to collect the biodiesel and glycerine in separate layers after some hours. It is mainly used for separation of biodiesel and its by-product after transesterification process.

6) Materials

Cooking oil i.e. Sunflower oil is purchased from a retail store. Pure methanol and KOH is purchased from Chennai Chemicals, Parrys, Chennai.

Fig 1.Biodiesel Production Setup

B. Titration

To determine the percent of FFA in the oil, a process called titration is used. The oil is first mixed with methanol. Next, a mixture of Potassium Hydroxide (KOH) and water is added until all of the FFA has been reacted and it is confirmed by checking the pH of the mixture. If the pH is about 9 , it confirms that all of the FFA has been reacted. Thus, the free- fatty acid content in sunflower oil is less than 2.5%.

C. Mixing of Methanol and Catalyst

The purpose of mixing methanol and the catalyst (KOH) is to react two substances to form Methoxide. For the formation of Methoxide Methanol used should be 20% of the volume of the oil. KOH does not readily dissolve into Methanol. When particles of KOH cannot be seen, the Methoxide is ready to be added to the oil. This can usually be achieved in 20–30 minutes. For 2 litres of sunflower oil, 500ml methanol and 11g of Potassium hydroxide is mixed together for carrying out transesterification process.

D. Heating of Oil

Since the ideal temperature range for the reaction is 55-60 ^{0}C, to speed up the reaction, the oil must be heated . The reaction can take days at room temperature and will be inhibited above 600C. This will result in a For even heating and reduce the temperature of oil exposed directly to the heating element the oil must be stirred ass it is heated.

E. Transesterification Process

Biodiesel is generally produced by base catalysed transesterification process as it is the most economical process, requiring only low temperatures and pressures while producing a 98% conversion yield. The transesterification process is the reaction of a triglyceride (fat/oil) with an alcohol to form esters and glycerol. A triglyceride has a glycerine

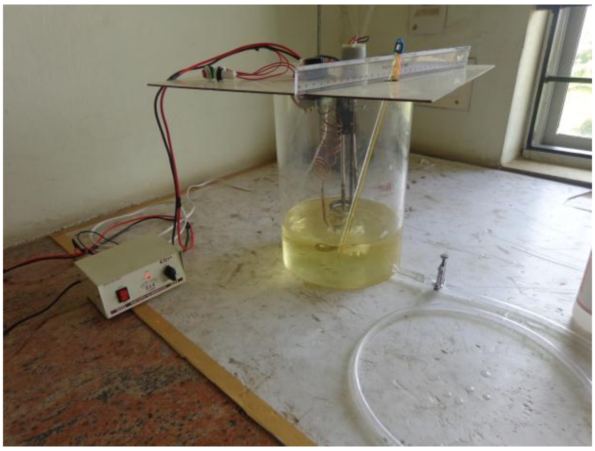

Fig 2: Heating the oil

molecule as its base with three long chain fatty acids attached.

During the transesterification process, the oil is heated up to 55-60 0C. Then the mixture of methanol and catalyst is added to the oil and stirred well for about 30-40 minutes. The triglyceride is reacted with alcohol in the presence of a catalyst - a strong alkaline like sodium hydroxide or potassium hydroxide. The alcohol reacts with the fatty acids to form the mono-alkyl ester, or biodiesel, and crude glycerol. A successful transesterification reaction is shown by the separation of the methyl ester (biodiesel) and glycerol layers after the reaction time

Fig 3: Transesterification process

F. Draining of Glycerol

One must wait for the glycerol to settle to the bottom of the container after the transesterification reaction. This happens because Glycerol is heavier than biodiesel. The settling will begin immediately, but the mixture should be left a minimum of eight hours to make sure all of the Glycerol has settled out. The volume of Glycerol should be ~ 20% of the original oil volume.

Fig 4: Settling of Glycerol

G. Washing of fuel

The washing of raw biodiesel fuel is needed in order to wash out the remnants of the catalyst and other impurities. A small amount of distilled water is added to the raw biodiesel and shaked well so as to remove excess chemicals. Then the water is poured out and then the biodiesel is heated upto 500C so as to remove the moisture from the fuel.

Fig 5: Washing of fuel

H. Extracted biodiesel

Biodiesel from sunflower oil was extracted using this setup with yield of about 80%. The properties of the biodiesel extracted were studied.

Table 1
PROPERTIES OF BIODIESEL

PROPERTIES	DIESEL	BIODIESEL
Density(15^0C) (Kg/m^3)	833	886
Kinematic viscosity(40^0C) in CST	2.84	4.3
Flash point(^{0}C)	50	272
Calorific Value (MJ/kg)	42.7	38.2

Fig 6: Extracted Biodiesel

IV. EXPERIMENTAL SETUP AND MEASUREMENT

The experiments were conducted in Kirloskar AV1 make water cooled four stroke diesel engine. The rated power of the engine is 5.20 kW running at a constant speed of 1500 rpm. The schematic view of the experimental setup is given in the Figure 1. Engine is connected with the swinging field electrical generator with load bank. The engine specification is given in the table 2.2. AVL-444 gas analyzer is used to measure the HC, CO and Nox emissions. The smoke opacity was measured using AVL-437 Hatridge smoke meter. The exhaust gas temperature was measured using K-type thermocouples. Piezoelectric pressure sensor was used to measure the in-cylinder pressure at every crank angle (CA) by a charge amplifier transducer in the range of 0-100 bar.

TABLE 2
ENGINE SPECIFICATION.

Type	Kirloskar AV 1, Water cooled , Four Stroke
Number of cylinders	Single
Bore	87.5 mm
Compression ratio	17.5:1
Maximum power	5.20 kW
Speed	1500 rpm
Dynamometer	Electrical
Injection pressure	200 bar

Parameters such as engine speed, fuel flow, and emission characteristics were obtained from the data acquisition system connected to the engine. Brake thermal efficiency, brake power, and specific fuel consumption were evaluated from the above parameters to study the performance of the engine. The combustion characteristics such as cylinder pressure and heat release rate were noted for biodiesel with different nanoparticles concentrations.

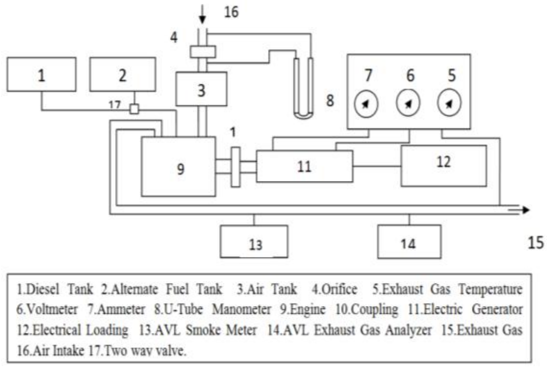

Fig 7: Experimental Setup

V. TEST PHASES

The various phases of tests on the above setup are carried out on the following phases.

1. Running the engine with diesel alone.
2. Running the engine with different blend ratios with Biodiesel (Esterified Sunflower oil) and diesel as follows

- 20:80 (Esterified Sunflower oil: Diesel)
- 100 - Esterified Sunflower oil

VI. RESULTS AND DISCUSSION

The experiment was conducted on a four stroke single cylinder direct injection water cooled diesel engine. The engine is fuelled with biodiesel and blend of biodiesel i.e. B20 and the performance and emission characteristics were discussed and compared with neat diesel.

A. PERFORMACNE CHARACTERISTICS

1) Specific fuel consumption

The specific fuel consumption of diesel, biodiesel and its blend are shown in the figure 8. The sunflower oil biodiesel has higher specific fuel consumption compared to diesel for all load conditions. Sunflower biodiesel has low calorific value compared to diesel, hence more amount of fuel was consumed to produce same power output. It is observed that specific fuel consumption increases by 19% and 12.85% for biodiesel and B20 blend compared to that of diesel at full load.

2) Brake Thermal Efficiency

The brake thermal efficiency of diesel, biodiesel and its blend are shown in the figure 9. The sunflower oil biodiesel has lower BTE compared to that of diesel. The primary cause of lower BTE is higher viscosity, density than diesel. Higher viscosity decreases atomization and fuel vaporization, which results in a more uneven combustion than that of diesel fuel. B20 blend has improved BTE than that of biodiesel. It is observed that BTE decreases by 16% and 9% for biodiesel and B20 blend compared to that of diesel at full load.

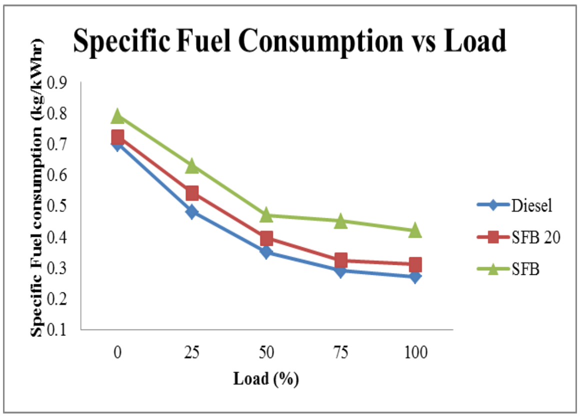

Fig 8: Specific fuel consumption against load

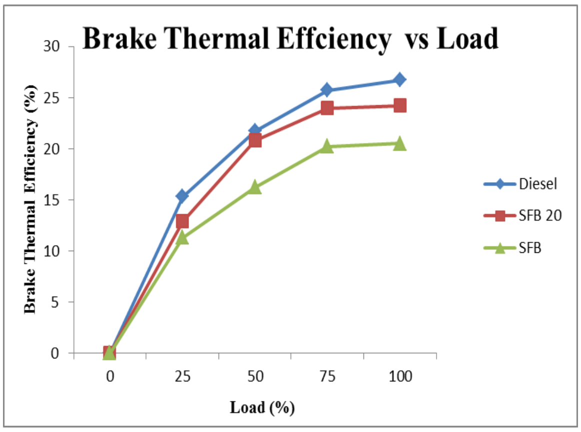

Fig 9: Brake thermal efficiency against load

B. EMISSION CHARACTERISTICS

1) Carbon monoxide

The figure 10 shows the variation of carbon monoxide(CO) emission of diesel, biodiesel and its blend with respect to load. By using biodiesel, reduction in CO is observed which is due to the increased proportion of oxygen in biodiesel compared to diesel which promotes oxidation and results in complete combustion. Thus, there is a decrease of 33.5% and 20.2% for biodiesel and B20 blend compared to that of diesel at full load.

2) Hydrocarbon(HC)

The figure 11 shows the variation of Hydrocarbon(HC) emission of diesel, biodiesel and its blend with respect to load. Since, biodiesel has higher oxygen content which results in complete combustion of fuel. Thus, HC is less compared to that of diesel. The increased gas temperature and higher cetane number of biodiesel and their blends were responsible for this decrease. Thus, there is a decrease of 26.5% and 14.7% for biodiesel and B20 blend compared to that of diesel at full load.

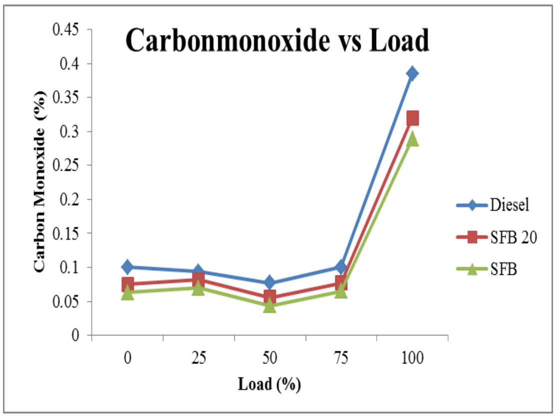

Fig 10: Carbon monoxide against load

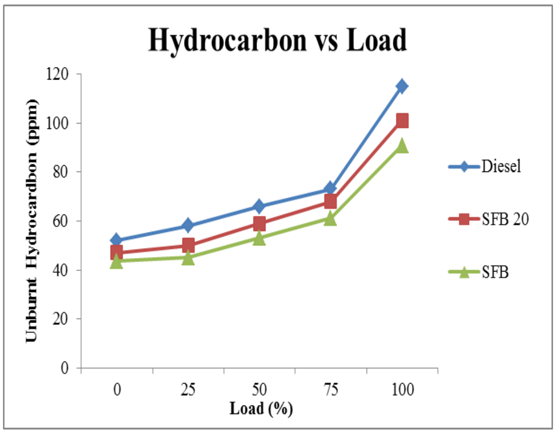

Fig 11: Hydrocarbon against load

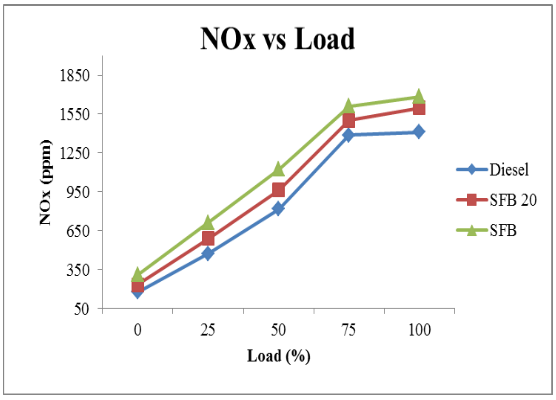

Fig11: Oxides of Nitrogen against load

3) Oxides of Nitrogen(NOx)

The figure shows the variation of Oxides of Nitrogen(NOx) emission of diesel, biodiesel and its blend with respect to load. The NOx from biodiesel is higher compared to that diesel. This is mainly due to presence of oxygen and higher cetane number of biodiesel blends. Hence the ignition delay is reduced which leads to better combustion resulting higher operating temperature. The inert nitrogen reacts with oxygen at higher temperature to form NOx. Thus, there is an increase of 16.2% and 11.5% for biodiesel and B20 blend compared to that of diesel at full load.

VII. CONCLUSION

Based on the results obtained from performance and emission characteristics of diesel, biodiesel and its blend, the following conclusions were made.

- There is a slight increase of specific fuel consumption for B20 blend and biodiesel than that of diesel
- Brake thermal efficiency decreases by 16% and 9% for biodiesel and B20 blend than that of diesel
- There is a significant reduction in CO and HC emission than that of diesel
- There is a slight increase in NOx emission due to high oxygen content in biodiesel.

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